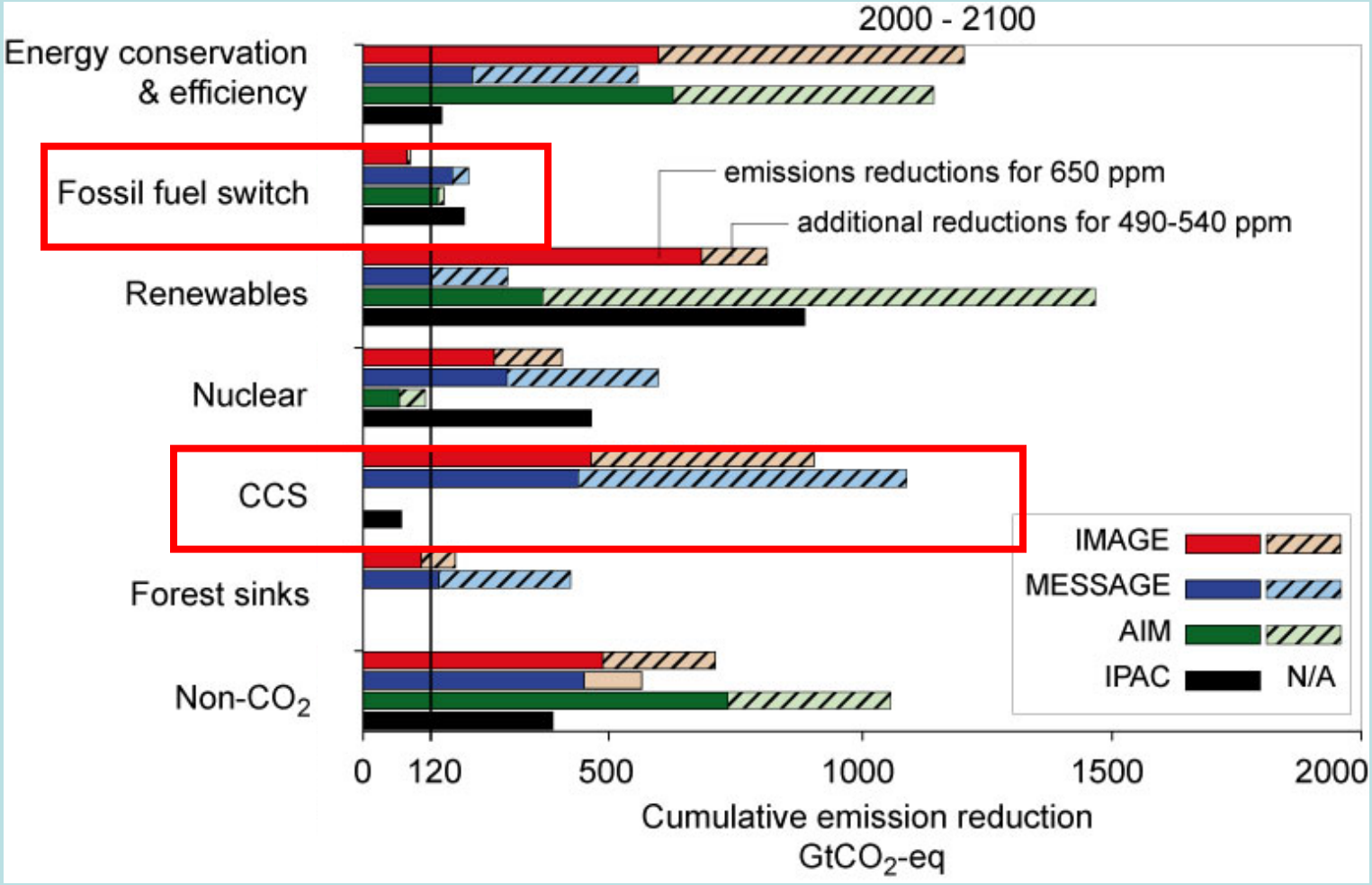
Methane Hydrates: CO_2 storage and natural gas production

$CO_2 \longrightarrow$  $\longrightarrow CH_4$

Klaus Wallmann, GEOMAR Research Centre, Kiel, Germany

Hydrate technologies may contribute to the reduction of CO_2 emissions from fossil fuel power plants

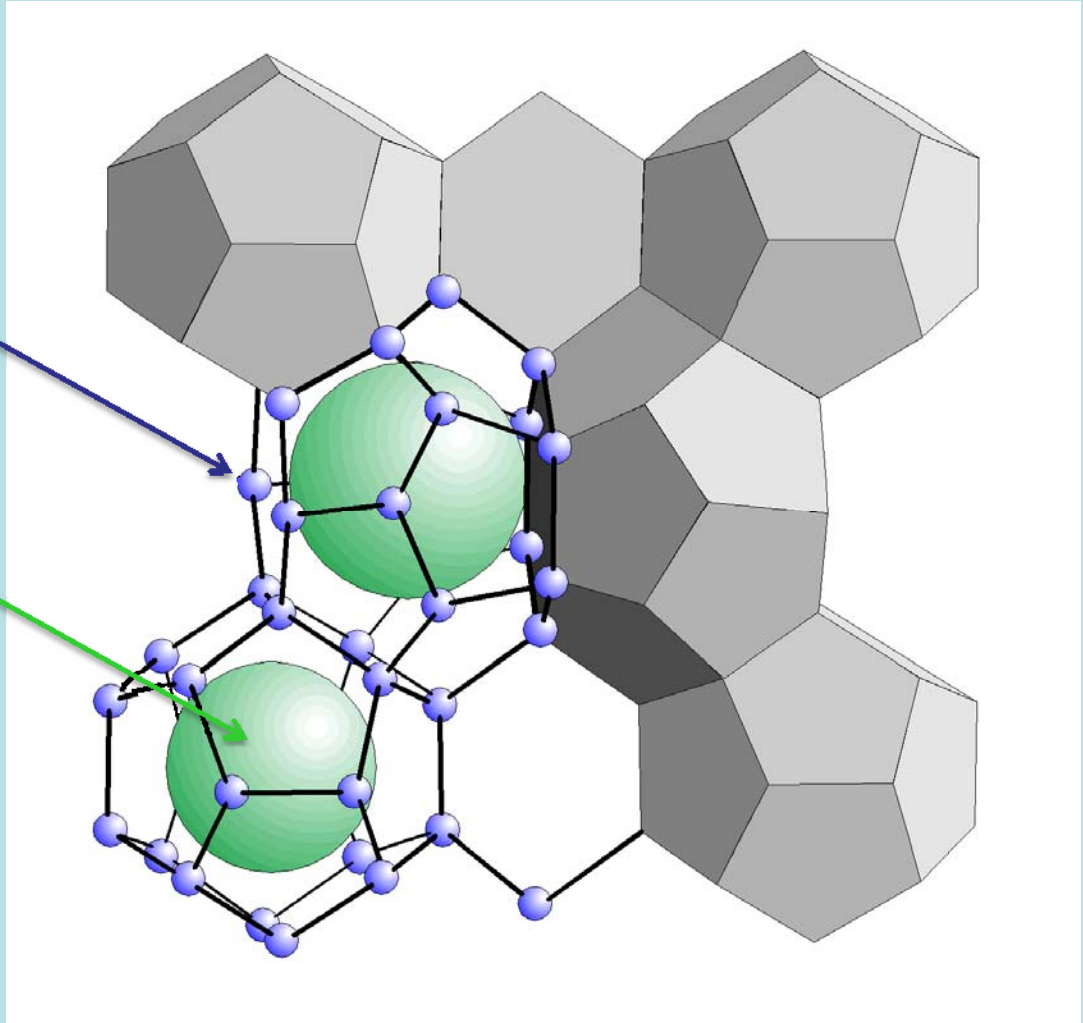


Source: IPCC (2007): Climate Change - Mitigation

Molecular structure

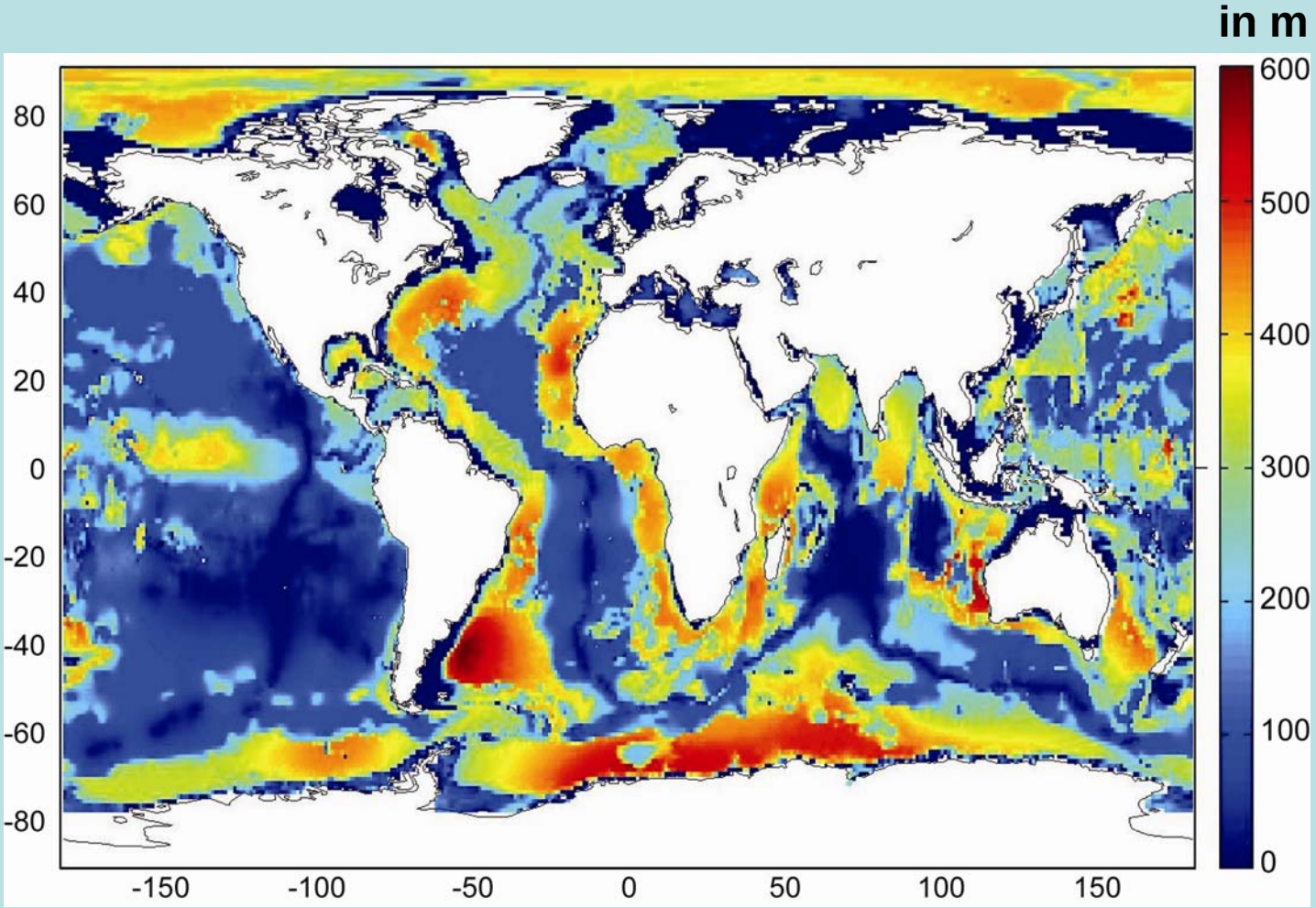
Water cage

Methane molecule



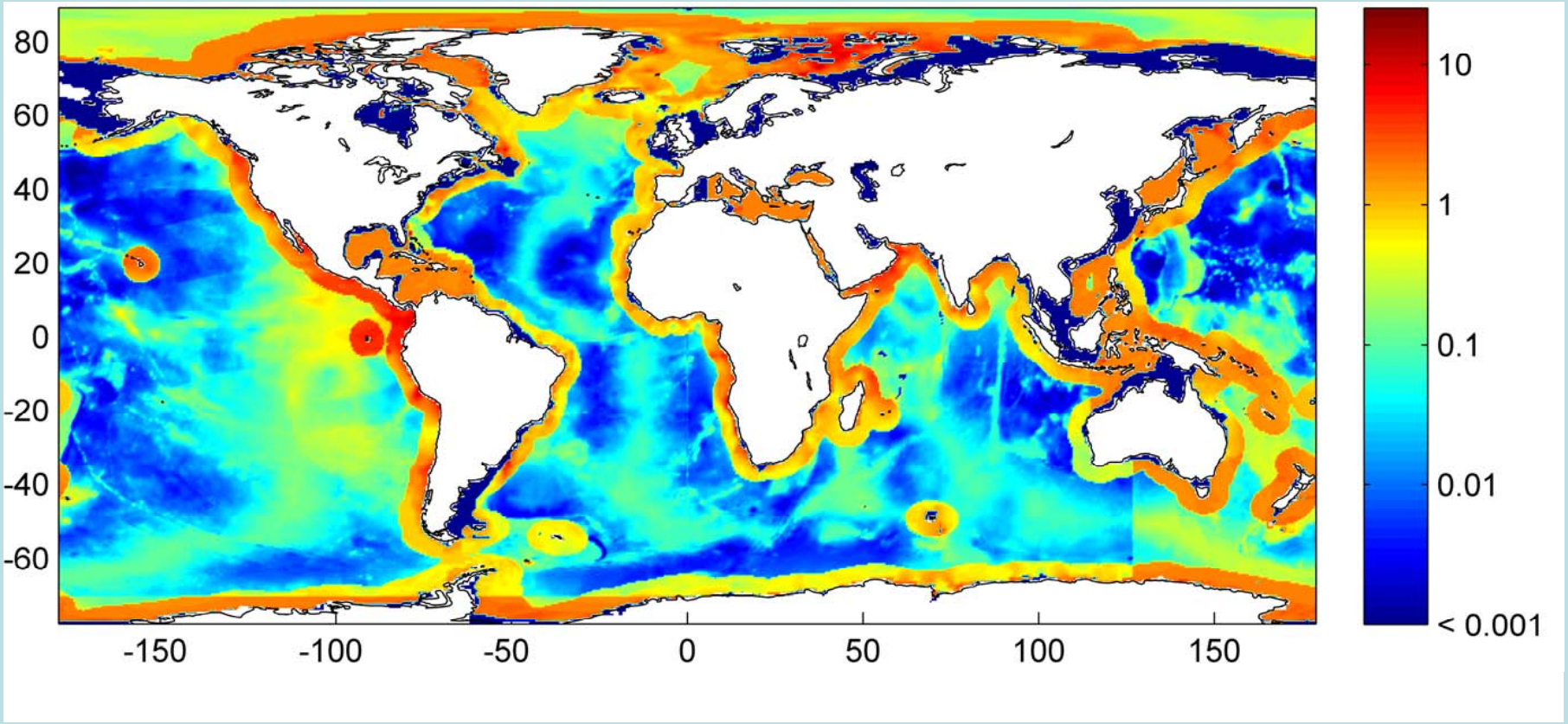
Only stable at high pressure and low temperature

Thickness of the methane hydrate stability zone in marine sediments



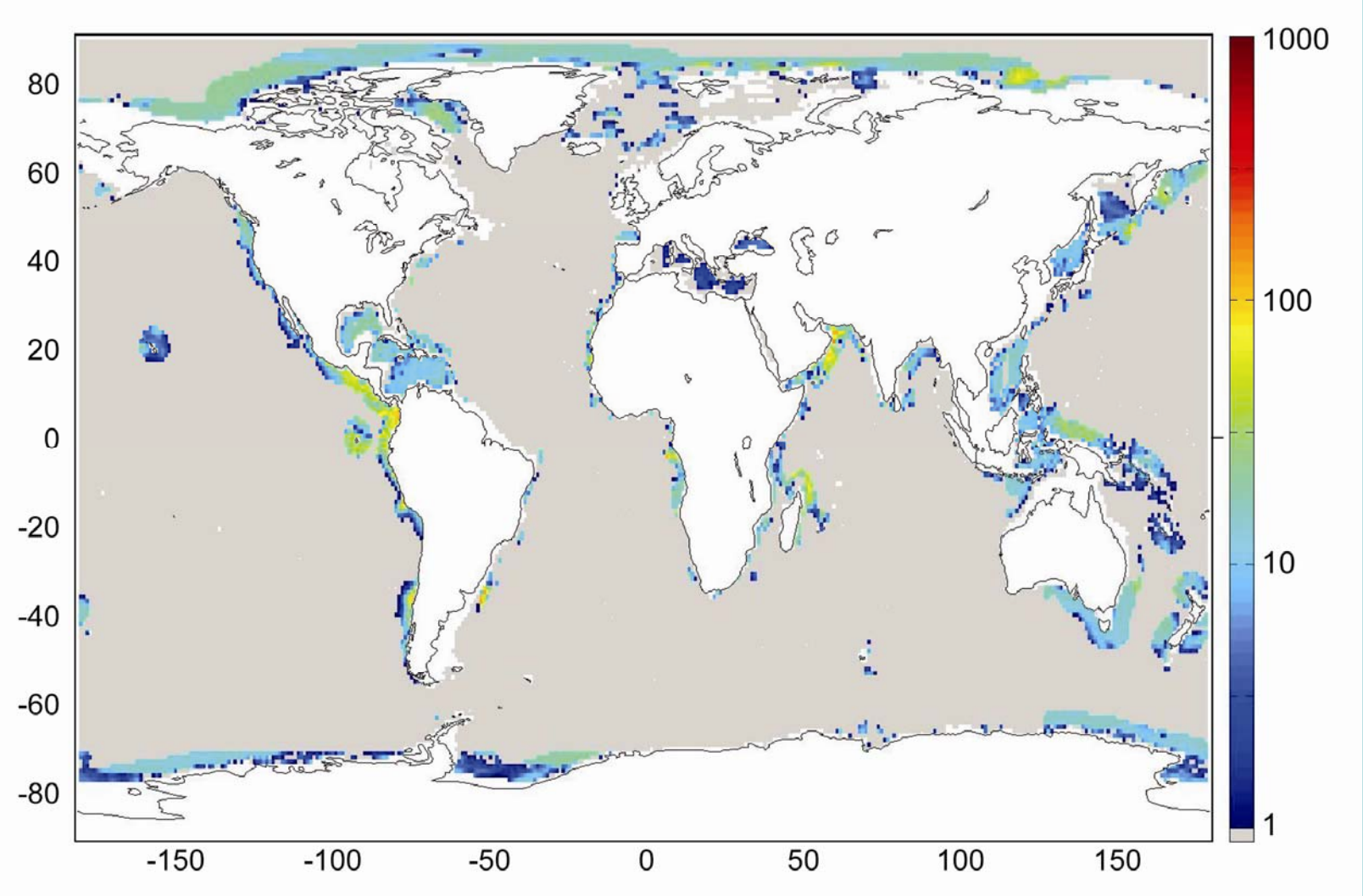
Source: Wallmann et al. (2012), Energies, 5, 2449-2498, special volume on gas hydrates

Mean Quaternary organic carbon accumulation rates at the seabed (in g m^{-2} yr^{-1})



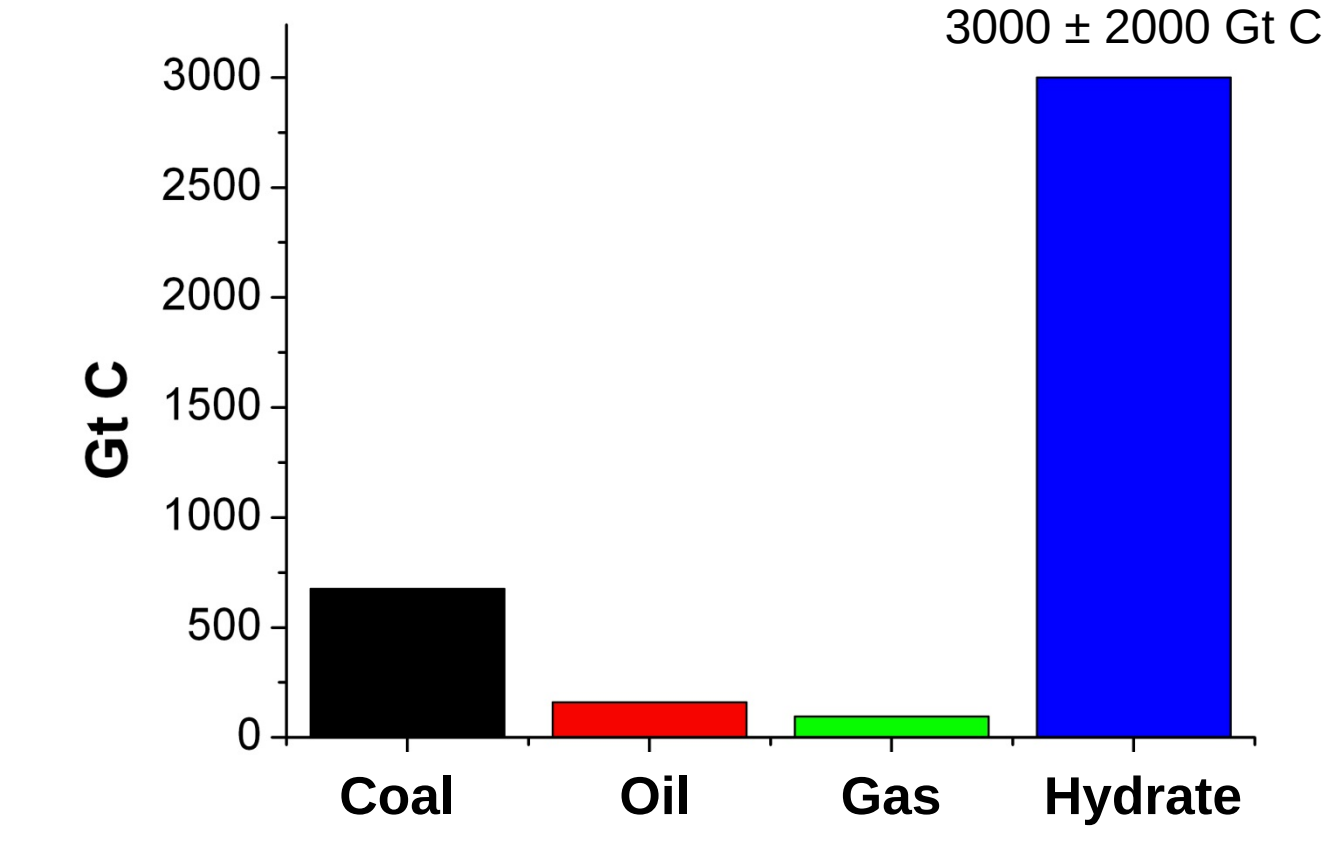
Source: Wallmann et al. (2012)

Global distribution of methane hydrates in marine sediments (in kg C m^{-2})



For Quaternary boundary conditions and full compaction (Wallmann et al. 2012)

Global inventories of fossil fuels



Source: Energy Outlook 2007, Wallmann et al. (2012)
Coal, oil, gas: reserves economically exploitable at current market prices
Gas Hydrates: total marine inventory

Hydrate Exploitation

Methane gas may be produced from hydrate deposits via:

- Pressure reduction
- Temperature increase
- Addition of chemicals (incl. CO_2)

Hydrate Exploitation

Energy balance for gas production via heat addition at Blake Ridge (Makogon et al. 2007)
2000 m water depth, two ~3 m thick hydrate layers

~40 % of the potential energy can be used for energy production while ~60 % of the potential energy is lost during development, gas production, and transport

Japanese Hydrate Exploitation Program
Hydrate exploitation via **pressure reduction** has a **much better energy balance** and may be **economically feasible at an oil price of ~54 $/barrel.**

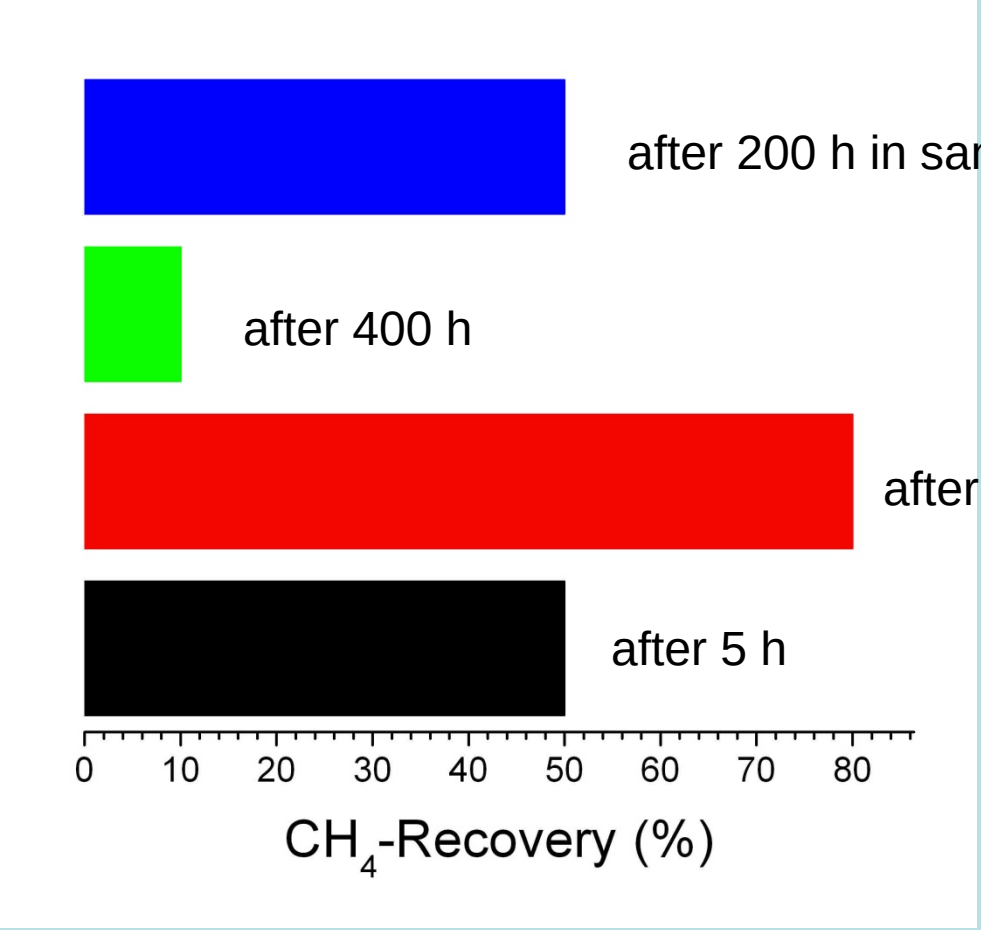
CH_4(g)-Recovery from Hydrates Exposed to CO_2

CO_2(l)
Kvamme et al. (2007)

CO_2(l)
Hiromata et al. (1996)

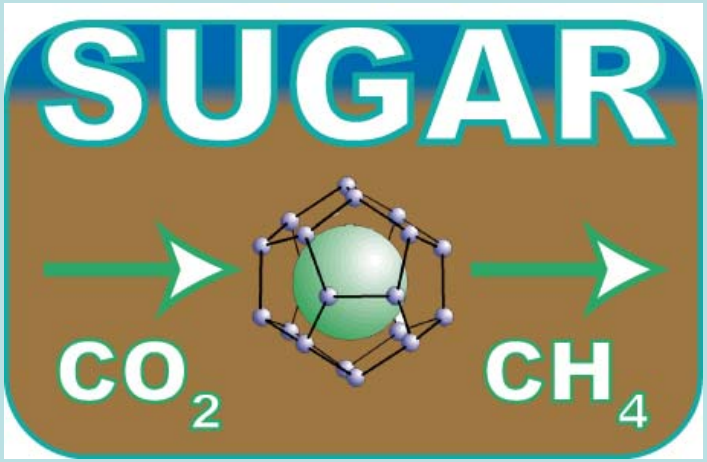
CO_2(g)/N_2(g)
Park et al. (2006)

CO_2(g)
Lee et al. (2003)



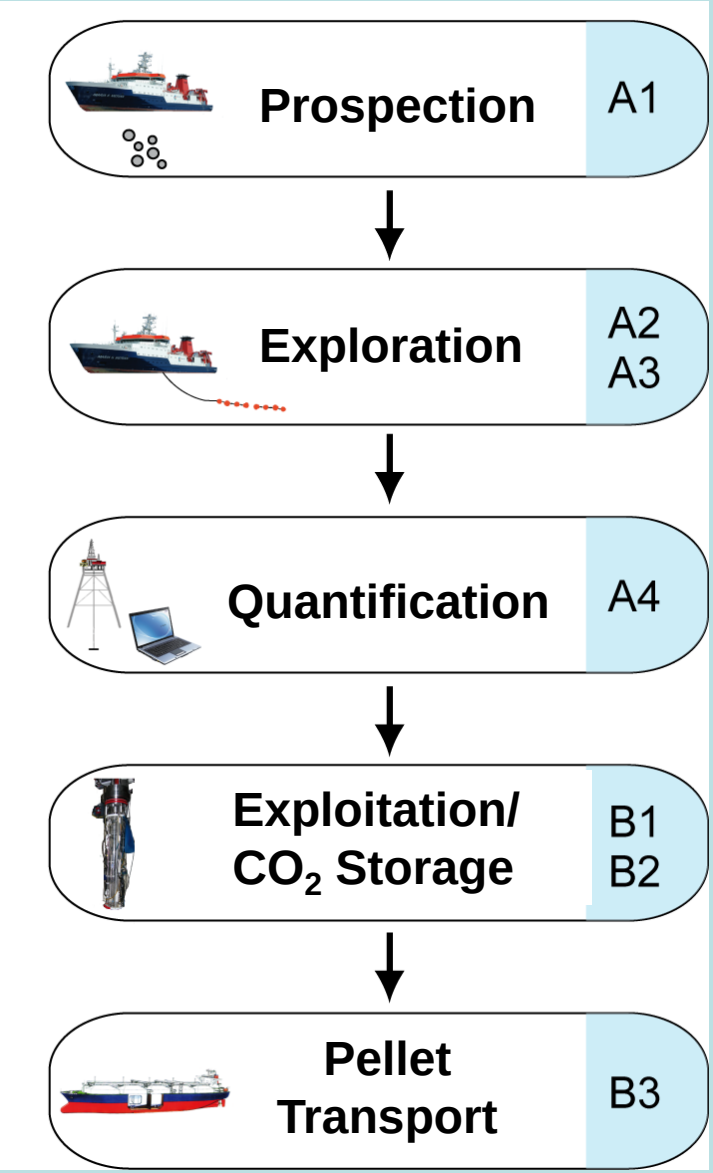
Spontaneous exothermic reaction !

The SUGAR Project



- Funded by German Federal Ministries (BMWi, BMBF)
- First funding period: July 2008 – June 2011
- Total funding: ~13 Mio € (incl. support by industries)

The SUGAR Project



A: Exploration

A1: Hydro-acoustics

A2: Geophysics

A3: Autoclave-Drilling

A4: Basin Modeling

B: Exploitation and Transport

B1: Reservoir Modeling

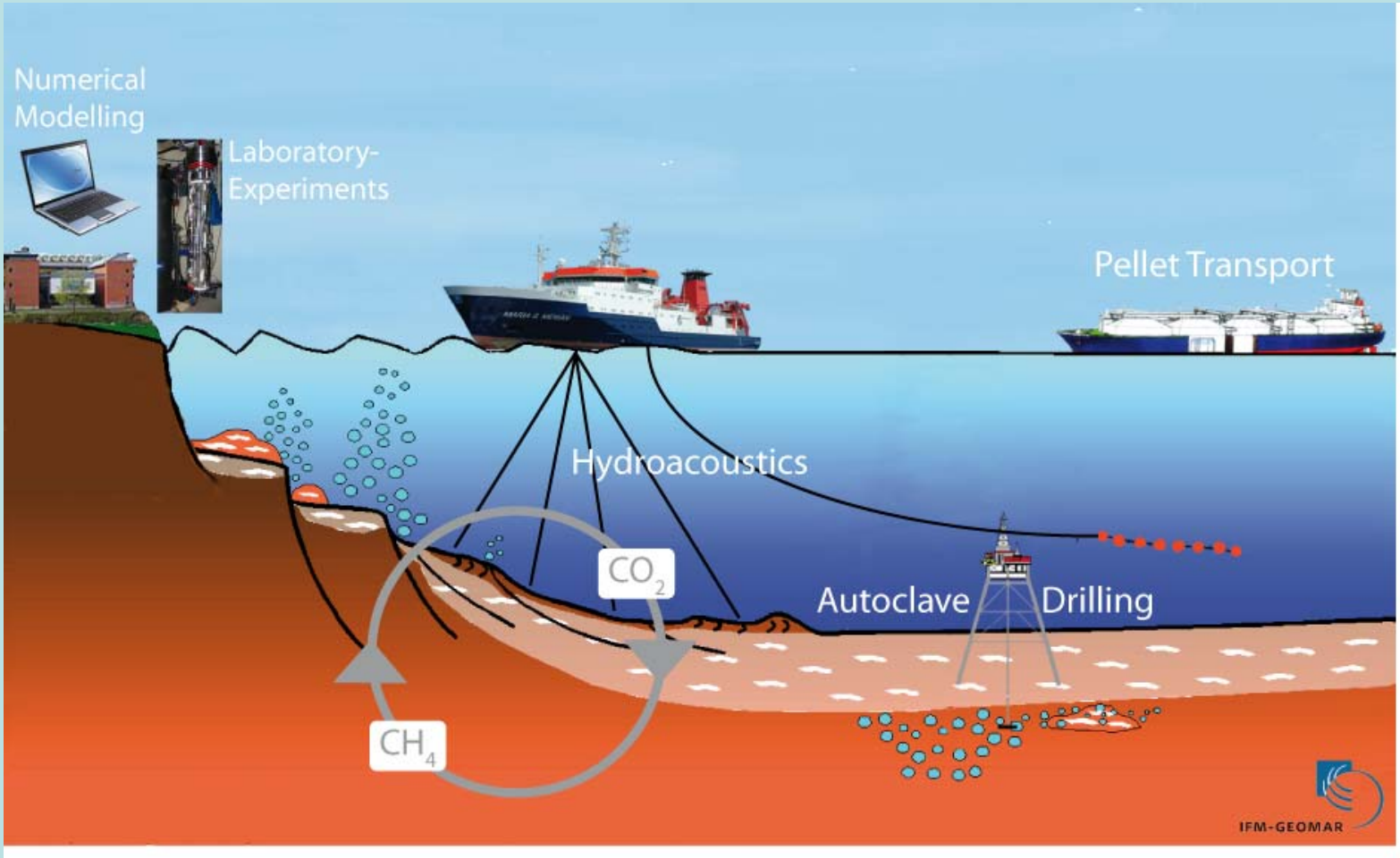
B2: Laboratory Experiments

B3: Gas Transport

SUGAR Partners

Project	Academia	Industries
A1	IFM-GEOMAR	L3 Communications ELAC Nautik GmbH
A2	IFM-GEOMAR, BGR Hannover	K.U.M. Umwelt- und Meerestechnik GmbH, Magson GmbH, SEND Offshore GmbH
A3	University of Bremen, TU Clausthal	Bauer PRAKLA Bohrtechnik GmbH
A4	IFM-GEOMAR	Schlumberger-IES
B1	Fraunhofer UMSICHT, GFZ Potsdam, IFM-GEOMAR	Wintershall, Aker-Wirth GmbH
B2	FH Kiel, GFZ Potsdam, Fraunhofer UMSICHT, IFM-GEOMAR, Uni Göttingen	BASF, CONTROS GmbH, R&D Center at FH Kiel, 24sieben Stadtwerke Kiel AG, RWE Dea, Wintershall, E.ON Ruhrgas AG
B3	IOW, FH Kiel	Linde AG, Meyer Yards, Germanischer Lloyd, BASF

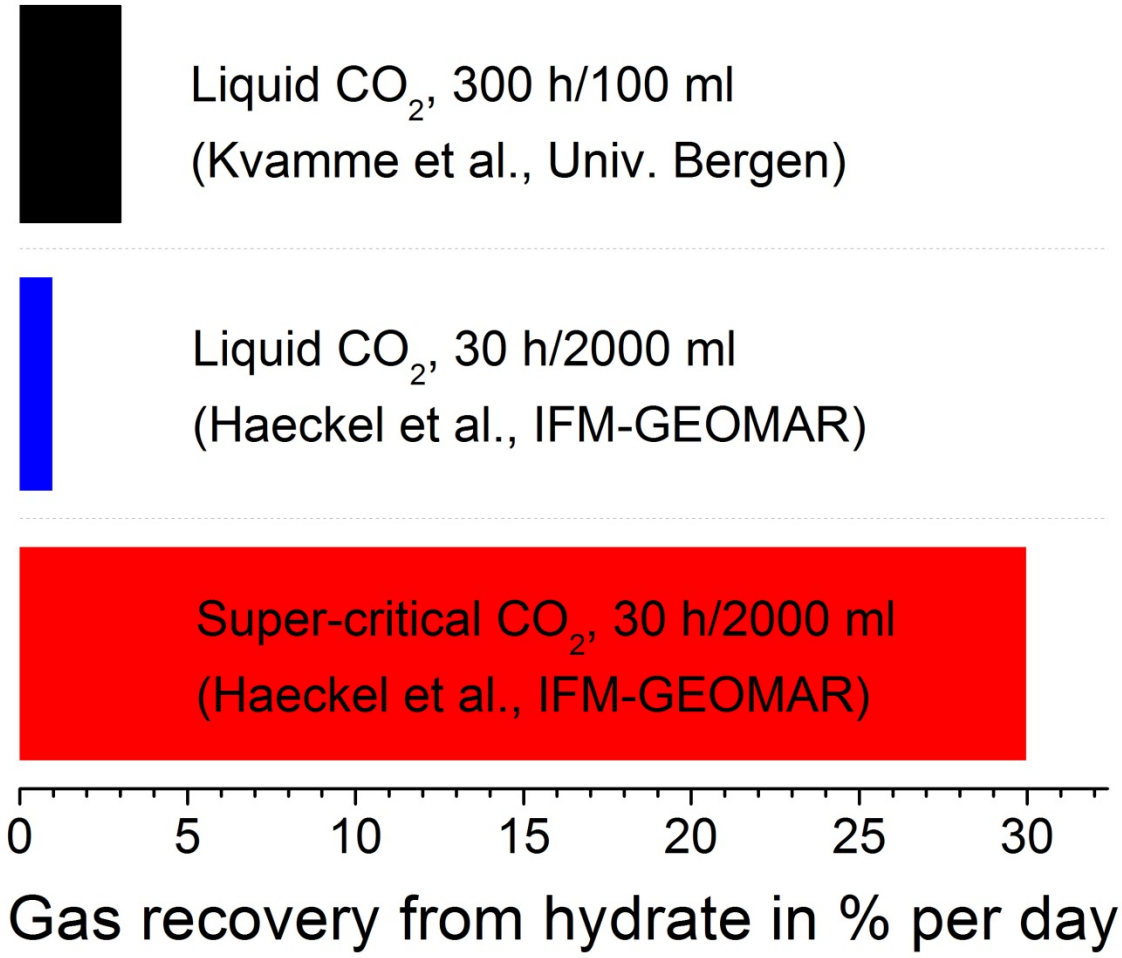
SUGAR Technologies



Major achievements phase I

- **Development and successful application of improved exploration techniques for high-resolution imaging of gas hydrates and sediment structures in the top ~0.5 km of the sediment column (hydro-acoustics, 3-D seismic, deep-towed 2-D seismic and CSEM, joint inversion of seismic and CSEM data, autoclave drilling, basin modeling)**
- **Development of improved production methods at lab scale applying combinations of pressure reduction, super-critical CO_2 injection, polymer addition and in-situ methane combustion.**

CH_4-recovery from hydrates in sand matrix exposed to CO_2



SUGAR Phase II

July 2011 – June 2014 (funded by BMWi, BMBF and RWE Dea)

A: Exploration

A1: Hydroacoustics & Sensors	**ELAC Nautik, CONTROS, IFM-GEOMAR**
A2: Geophysics & Drilling	**TEEC, CORSYDE, CONTROS, IFM-GEOMAR, BGR, MARUM**
A3: Basin Modeling	**Schlumberger AaTC, IFM-GEOMAR**

B: Exploitation

B1: Reservoir Modeling	**Wintershall, EON Ruhrgas, Fraunhofer UMSICHT, GFZ, IFM-GEOMAR**
B2: Laboratory Experiments	**RWE Dea, BASF, CONTROS, Fraunhofer UMSICHT, GFZ, Univ. Göttingen, IFM-GEOMAR**
B3: Drilling technologies	**Bauer, Aker-Wirth, TU Clausthal, TUB Freiberg, Univ. Bochum**

SUGAR Phase II

Major aims:

- **develop gas hydrates as an environmentally sound natural gas resource and medium for CO_2 sequestration**
- **quantify gas hydrate masses and distributions in the sub-surface via enhanced geophysical exploration, data analysis, autoclave drilling, and basin modeling**
- **enhance methane hydrate dissociation, methane gas release and CO_2 sequestration via a suitable combination of super-critical CO_2 and polymer injection, in-situ combustion, and depressurization**
- **reduce development and production costs and environmental risks by improved drilling and production technologies**

International contacts and cooperations

Bulgaria, Georgia, Romania, Russia, Turkey, Ukraine (Black Sea): Joint exploration cruises, joint workshop (March 27th – 28th, 2012)

New Zealand: Joint exploration cruises (2011, 2013)

US: Numerical basin simulation Alaska North Slope (2011 - 2014)

France (Total): Joint exploration cruise off West Africa (2012)

Taiwan: Joint exploration cruises (2013)

India: Joint workshops, RV Sonne proposal, pending

Norway (Statoil): Basin simulation GoM (2012 - 2015)

Japan, China, South Korea: Joint workshops and meetings

UNEP: Report on gas hydrates (2013)

EU: Coordinated program on environmental risks of sub-seabed CO_2 storage (ECO2: 2011 - 2015)

Field production tests (USA, Japan, South Korea)

On-shore Alaska (Prudhoe Bay, below permafrost)

2012 (DOE, CP, Japan): CO_2 **injection (short-term)**

~ 2014 (Statoil): **Pressure reduction (long-term)**

Off-shore Japan (~1000 m water depth)

2013 (MH 21): **Pressure reduction (short-term)**
2014 (MH 21): **Pressure reduction (long-term)**

Off-shore South Korea (~2000 m water depth)

2014: **Pressure reduction**
with German participation